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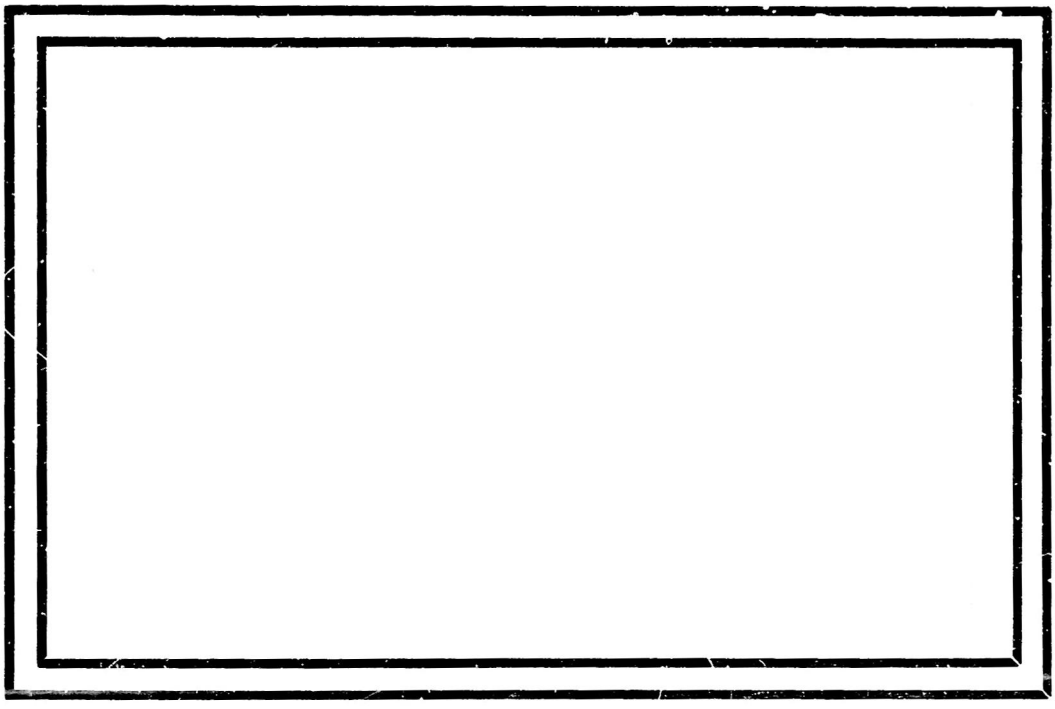

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NUCLEAR SHELL MODEL FT-VALUES for INTERMEDIATE COUPLING

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Letter to the Editor, The Physical Review

Nuclear Shell Model ft-Values for Intermediate Coupling

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Using the wave functions already calculated by one of us for various light nuclei of mass number from 6 to 15[1] we have evaluated the beta-decay matrix elements, and thus the ft-values, for several of the beta-transitions among the light nuclei. These theoretical results agree satisfactorily with experiment, [2] and indicate that intermediate coupling is to be preferred as a nuclear model over strict LS or j-j coupling. [3]

The present work depends upon the derivation of the nuclear wave functions, which used the shell model with intermediate coupling. Specific assumptions were:

1) Two protons and two neutrons fill the 1s shell, forming an inert core. The remaining nucleons lie in the 1p shell, whose one-particle space wave functions,

$r/r_0 \exp - 1/2\,(r/r_0)^2 \times Y_1^{1,0,-1}$ (where $r_0 = 1.7 \times 10^{-13}$ cm and $Y_1^{1,0,-1}$ are the spherical harmonics), are coupled to the Pauli spin functions by a spin-orbit force whose strength is such as to produce a $j = 3/2$, $= 1/2$ splitting of 2.0 Mev for a 1p nucleon moving in the field set up by the four 1s core nucleons.

2) The interaction between nucleon pairs is a four-forces mixture weighted 0.35 Wigner, 0.35 Majorana, 0.15 Bartlett, and 0.15

Heisenbert force, with a well depth of 30 Mev and a common radial dependence of $\exp - (r/1.9 \times 10^{-13}\text{cm})^2$. The spin-orbit force of 1) also acts between all nucleon pairs. The tensor force is neglected.

3) The wave functions contain no admixtures from higher shells -- the energy is diagonalized wholely within the 1p, (that is, $P_{3/2}$ and $P_{1/2}$), shell.

The above assumptions led to wave functions yielding magnetic moments in agreement with experiment to the accuracy with which 3) can be expected to hold, ($\sim$5 per cent). Using the same wave functions to calculate the matrix elements in $\log ft = C - \log (|\int 1|^2 + |\int \sigma|^2)$, (where we take the Fermi and Gamow-Teller coupling constants equal, and fit the constant C to the neutron ft-value), we find values which are presented in the table below and compared with those calculated on the basis of strict j-j coupling.

We are grateful to Prof. W. Heisenbert for suggesting and stimulating this work. One of us (RAF) is endebted to the Max-Planck-Institut for the hospitality extended to him, and to the U. S. Atomic Energy Commission for fellowship support.

β-Transition	Log ft Experimental [4]	j-j coupling	intermed. coupling
a) $n \rightarrow p + e^- + \nu$	3.13	3.13	3.13
$He^6 \rightarrow Li^6 + e^- + \nu$	2.94 ± 0.04	----	2.98
$Be^7 \rightarrow Li^7 + \nu$	3.37 ± 0.01	3.43	3.41
$Be^7 \rightarrow Li^{7*} + \nu$	3.53	4.06	~~3.67~~ 3.58
a) $C^{10} \rightarrow B^{10*} + e^+ + \nu$	3.77 ± 0.20	3.43	3.43
$N^{13} \rightarrow C^{13} + e^+ + \nu$	3.67	3.59	3.69
b) $C^{14} \rightarrow N^{14} + e^- + \nu$	8.95	3.99	5.70
a) $O^{14} \rightarrow N^{14*} + e^+ + \nu$	3.52 ± 0.10	3.43	3.43
a) $O^{15} \rightarrow N^{15} + e^+ + \nu$	3.59 ± 0.03	3.61	3.61

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1) R. Schulten, Doctoral Dissertation, University of Goettingen, (to be published). Zs. f. Naturforschung, 12, 759 (1953).

2) To roughly the experimental error, except for C^{14}, for which see footnote b) below.

3) For work already carried out on intermediate coupling see D. R. Inglis, Rev. Mod. Phys. 25, 390 (1953); N. Zeldes, Phys. Rev. 90, 416 (1953); A. M. Lane, Phys. Rev. 92, 839 (1953); G. E. Tauber and Ta - You Wu, Phys. Rev. 91, 443(A) (1953) and Bulletin Am. Phys. Soc. 29, 1, IA8 (1954); W. T. Sharp, H. Gellman, and G. E. Tauber, Bulletin Am. Phys. Soc. 29, 1, IA9 (1954).

4) We are endebted for information on the experimental data to R. W. King, National Research Council.

a) These entries do not represent new work. The Fermi transitions are independent of nuclear structure, while the O^{15} beta-decay is completely described by j-j coupling.

b) L-forbiddenness gives rise to a factor of ten in this matrix element, and a further partial cancellation of contributions occurs as conjectured by Sachs, (R. Sachs, Nuclear Theory, p. 347, Addison-Wesley Pub. Co., 1953). That this is at variance with Inglis' finding, (loc. cit., p. 442), may be due to the fact that our spin-orbit force acts between all nucleon pairs, being explicitly

$$V_{S\text{-}O}(1,2) = -2.8\ \text{Mev}\left[\vec{s}_1\cdot(\vec{r}_{12}\times\vec{p}_1)+\vec{s}_2\cdot(\vec{r}_{21}\times\vec{p}_2)\right]\frac{1}{\hbar^2}e^{-r_{12}^2/(1.9\times10^{-13}\,\text{cm})^2},$$

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"Dressed" Particles in Quantum Field Theory.*
James L. Anderson, University of Maryland. - In time dependent perturbation theory there exists a certain ambiguity in the breaking up of the Hamiltonian into two parts, one of which is to be considered as the perturbation. If one breaks the Hamiltonian into the two parts H_0 and H_I and calls H_I the perturbing part, then it would appear equally justified to break it into two other parts H_0' and H_I', where $H_0'=(H_0+K)$, $(H_I'=H_0-K)$, and to call H_I' the perturbation. Since now the eigenstates of H_0' are employed in the specification of initial and final conditions in the theory, one might determine H_0' (or K) by requiring that it describe properly the "dressed" particles of the theory. This means that H_0' must be so chosen that

$$\langle \Psi_0, T[\psi(x)\psi(y)]\Psi_0\rangle = \langle \Phi_0, T[\bar{\psi}(x)\bar{\psi}(y)]\Phi_0\rangle,$$

where Ψ_0 is the vacuum state of the interacting system, Φ_0 the lowest energy state of H_0', $\psi(x)$ and $\psi(y)$ are Heisenberg operators, and $\bar{\psi}(x)$ and $\bar{\psi}(y)$ are operators in an interaction representation defined by H_0'. The existence of an H_0' satisfying this condition and its relation to the renormalization program will be discussed.

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The Boltzmann Equation from the Statistical Mechanical Point of View.*
Melville S. Green, University of Maryland. - Recently Kirkwood and Green have given derivations of the Boltzmann equation from the so-called hierarchy of equations governing the distribution functions of n-uples of molecules. The present work will exhibit a derivation which is the first step of an expansion in powers of the concentration. If we call φ_n the distribution of the phases of an n-uple normalized so that the spacial distribution approaches 1, when all the molecules are far apart, it can be shown that for a spacially uniform situation the hierarchy can be written

$$\frac{\partial}{\partial t}\varphi_n = -c\sum_{i=1}^{n}\nabla_{p_i}\int F_{in+1}\varphi_{n+1}\,dp_{n+1}\,dx_{n+1},$$

where the right-hand side is the total time derivative along a trajectory of an isolated system of n molecules, c the concentration, F_{in+1} the force between the ith and the n+1th molecule, and p_i, x_i the momentum and position of the ith molecule. These equations are solved by considering the left-hand side to be a small perturbation. The first step in the procedure leads to the Boltzmann equation for φ_1 as well as to expressions for φ_n which are functionals of φ_1.

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